§ 8. Design of Evacuated Transmission Line for CW Operation of ECH System

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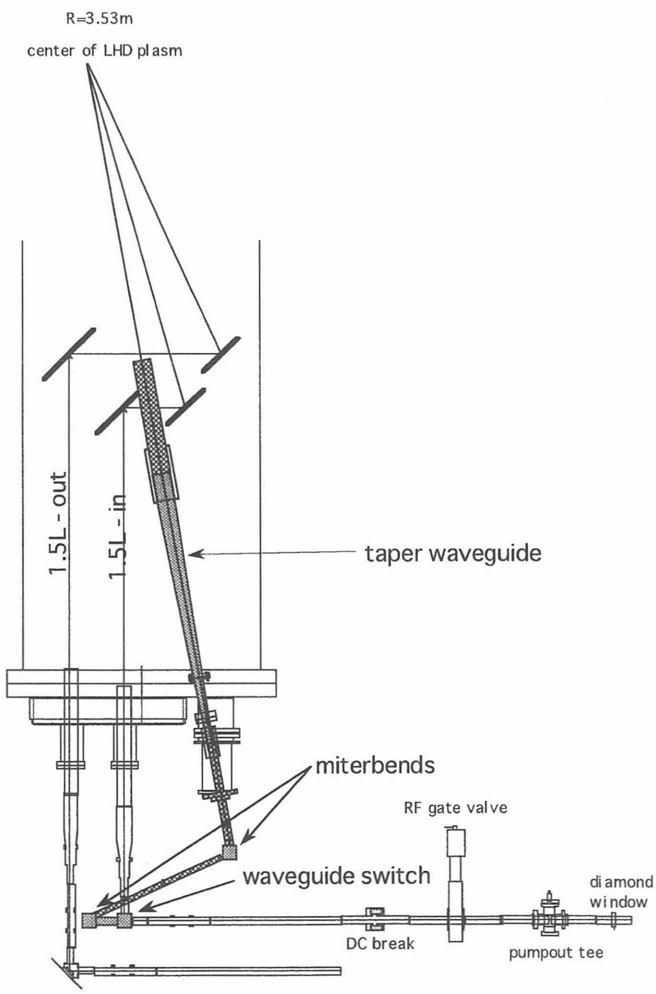
During the LHD 6th experimental campaign, by using two evacuated 31.75mm inner diameter corrugated waveguide transmission lines, EC-wave power up to 400kW each was stably delivered. Those lines connect #4 and #5 84GHz CPD gyrotrons at the heating equipment room to beam injection antenna systems named 1.5L-out and 1.5L-in at LHD 1.5L port. For next 7th experimental campaign, CW-gyrotron is going to be used for the sake of demonstration of long time plasma sustainment which is one of the excellent features of LHD adopting super-conducting magnets.

For CW operation, proper cooling is required because even small loss of transmitted power results in considerable temperature increase if some parts are thermally isolated. The two evacuated transmission lines furnish cooling channel at each 90 degree corner (miterbend) mirrors. Then we decided to modify one of the two lines for CW operation and use the transmission line alternatively with new CW gyrotron and #4 or #5 gyrotron. From the view point of simplicity of modification in the heating equipment room where gyrotrons are installed, the transmission line for #5 gyrotron is selected because #5 gyrotron and the CW gyrotron are set in line.

Using the most part of the transmission line commonly with the CW and #5 gyrotrons, both sides are reconstructed using waveguide switch (SW). At the heating equipment room, the first miterbend in front of #5 gyrotron is exchanged by a SW and waveguide is extended to the CW gyrotron. By the SW, power transmission from #5 or CW gyrotrons can be selected.

At the part near 1.5L port, another SW is used to select the way of injection. The 1.5L-in antenna system consists of a focusing mirror and a 2D-rotatable plane mirror, and has worked well for localized heating. However, the mirrors have no cooling channel so they can not be used for CW operation. Then direct power injection from a waveguide antenna is planned. Temperature increase due to power loss at the waveguide wall is considered to be low and the waveguide antenna would be available for CW operation without water cooling inside the LHD vacuum vessel. Up-tapering of waveguide size is important in this case because power release from thin waveguide results in much expanded beam radius at equatorial plane. For example, assuming the waveguide mouth being 1650mm below the equatorial plane, the beam from 31.75 / 63.5 / 88.9mm ID waveguides has radius of 185 / 95 / 73mm at the plasma center, respectively.

According to experimental requirement, ways of power injection can be changed flexibly. When high power ECH is required as before, power from #5 gyrotron is diverted to 1.5L-in antenna by the SW near 1.5L port. On the other hand, when CW plasma sustainment is aimed, power from CW gyrotron go through the SW. Using two miterbends, the power is delivered to taper waveguide inserted to LHD vacuum vessel. Also, long pulse power injection from 1.5L-in antenna can be performed provided monitoring the temperature increases of the mirrors. With the temperature data, power loss on the surface of SUS mirrors can be estimated experimentally. Obtained data will be useful to design mirror cooling system for CW focused beam injection in future.



A schematic view of designed CW power injection system. Dotted parts are added to previous transmission line.